More Energy Problems

Apply the law of conservation to the following problems.

1. How much energy is required to throw a 1kg rock to the moon? Ignore the pull of the moon.

Orbital radius of the moon = 3.85 x 108 m

Ethrow = work done to get the rock to the moon =

= ΔEg

= GMm [1/R1 – 1/R2]

= 6.67x10-11 (5.97x1024)(1)[1/6.37x106 – 1/3.85x108]

= 6.15x107 Joules

So 60 million Joules are required.

1. How much energy is required to move a 1000kg stationary satellite from:
2. the ground to one Earth radius altitude

W= ΔEg

= GMm [1/R1 – 1/R2]

= 6.67x10-11 (5.97x1024)(1000)[1/6.37x106 – 1/(2x6.37x106)]

= 3.13x107 Joules

1. one Earth radius altitude to two Earth radii altitude

W= ΔEg

= GMm [1/R1 – 1/R2]

= 6.67x10-11 (5.97x1024)(1000)[1/(2x6.37x106) – 1/(3x6.37x106)]

= 1.04x107 Joules

1. two Earth radii altitude to three Earth radii altitude

W= ΔEg

= GMm [1/R1 – 1/R2]

= 6.67x10-11 (5.97x1024)(1000)[1/(3x6.37x106) – 1/(4x6.37x106)]

= 5.21x106 Joules

1. In reference to the previous question: as we get farther from Earth, the energy required to travel a given distance gets \_\_\_smaller\_\_\_\_.
2. A 3000kg booster is disconnected from the space shuttle when it reaches an altitude of 72km. The booster falls from rest, its parachutes failing to deploy. Find the speed that the booster hits the water, ignoring air friction.

Classic E = E’:

Eg = Eg’ + Ek’

-Ek’ = Eg’ – Eg (switched the Eg and Ek)

- Ek’ = ΔEg

Ek’ = - ΔEg

½ mv2 = -GMm[1/R1 – 1/R2]

v2 = -2GM [1/R1 – 1/R2]

= - 2 (6.67x10-11)(5.97x1024)[1/6442000 – 1/6370000]

= 1397341

v = 1182 m/s

So the booster hits the water at about 1200m/s or 1.2km/s

1. A satellite has to be put into orbit in two phases: first it has to be put at the correct orbital altitude then it must be accelerated to the correct orbital velocity. Calculate the energy required to put a 2.125x106 kg satellite rocket into an orbit 180km above the Earth.

E = E’

Efuel + Eg = Ek’ + Eg’

Efuel + Eg = -1/2Eg’ + Eg’ for a satellite

Efuel + Eg = 1/2Eg’

Separate calculations, to make it easier to understand:

Eg = -GMm/R (starts on Earth’s surface)

= -6.67x10-11(5.97x1024)x(2.125x106)/6.37x106

= -1.33x1014 Joules

Eg’ = -GMm/R (ends in orbit)

= -6.67x10-11(5.97x1024)x(2.125x106)/6.55x106

= -1.29x1014 Joules

So back to our original calculation:

Efuel + Eg = ½ Eg’

Efuel = ½ Eg’ – Eg

Efuel = ½ (-1.29x1014) – (-1.33x1014)

= 6.85 x 1013 Joules

1. In reference to the above question, a small amount of energy can be saved by taking into account the velocity of the rotation of the earth. Assuming the rocket is launched from the equator find the percent of energy savings.

On equator, travel one rotation every day

V = 2πR/T

= 2(3.14159)(6.37x106)/(24x60x60)

= 463 m/s

So Ek = ½mv2

Ek = ½ (2.125x106)(463)2

Ek = 2.28x1011 Joules

So Efuel = 6.85 x 1013 - 2.28x1011 Joules

Efuel = 6.83 x 1013 Joules

Percent savings = 2.28x1011/6.85x1013 x 100% = 0.33% savings.

1. A 25000kg space probe has 1 MJ of fuel in its tanks. It is currently floating at roughly zero velocity at an altitude of 1000km above the Earth. How far can it travel on its fuel?

The problem with this question is that you won’t go far with only 1MJ of energy. To see your answer, you’ll need to keep a lot of digits for R.

E = E’

Eg + Efuel = Eg’

Efuel = Eg’ – Eg

Efuel = ΔEg

1.0x106 = GMm(1/R1 – 1/R2)

1.0x106 = 6.67x10-11(5.97x1024)(25000)[1/(7370000) – 1/R2]

1.0x106 = 9.95x1018 [1.356852x10-7 – 1/R2]

1.005x10-13 = 1.356852x10-7 – 1/R2

-1.356851x10-7 = -1/R2

R2 =7370005 m

Therefore, you only travel 5m! This may seem strange, but using the grade 11 method, you get roughly the same answer:

Efuel = mgh

1x 106 = 25000(9.81)(h)

H = 4.1m

1. A satellite of mass 6000kg in orbit at 200km altitude is moved to an orbit of 300km. How much energy is required to make the move? [NOTE: the satellite is moving in each orbit]

E = E’

Eg + Ek + Efuel = Eg’ + Ek’

Eg - ½Eg + Efuel = Eg’ – ½Eg’

½ Eg + Efuel = ½ Eg’

Efuel = ½ Eg’ – ½ Eg

Efuel = ½ ΔEg

Efuel = ½ GMm[1/R1 – 1/R2]

Efuel = ½ 6.67x10-11(5.97x1024)(6000)[1/6570000 – 1/6670000]

Efuel = 1.195x1018 [2.28x10-9]

Efuel = 2.73x109 Joules

It takes 2.7 billion Joules just to move it 100km !